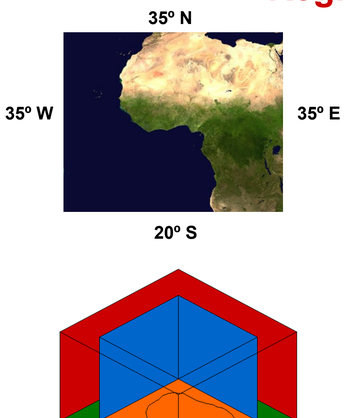
Study of West African Monsoons Through Forecast-Driven Regional Climate Model Simulations

Egbuta Oji, David Thomason, Sarah Dapul-Weberman

Abstract

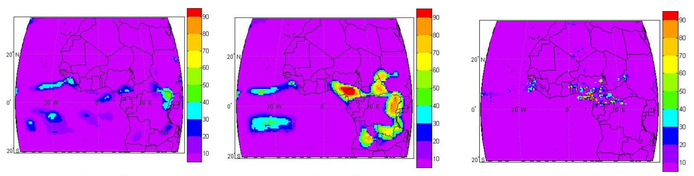
The RM3 Regional Model, developed at the Center for Climate Systems Research of Columbia University and the NASA Goddard Institute for Space Studies (GISS), has been configured to simulate forecasts over West Africa by taking lateral boundary condition data from the National Center for Environmental Prediction's (NCEP) Global Forecast System (GFS). These boundary conditions are provided in 1° resolution and are downscaled to the model's 0.5° resolution. The model is currently running at both NASA GISS and the headquarters of the African Center of Meteorological Application for Development (ACMAD) in Niamey, Niger. The outputs are then posted on the ACMAD website. To ensure that the people who utilize the resources provided by ACMAD are getting useful information from the RM3, the model must be constantly monitored and validated at NASA GISS. To accomplish this, comparative analyses have been done between RM3 and TRMM (Tropical Rainfall Measuring Mission satellite) for precipitation validation, as well as against NCEP Reanalysis II for wind circulation and surface temperature validation.

Regional Model



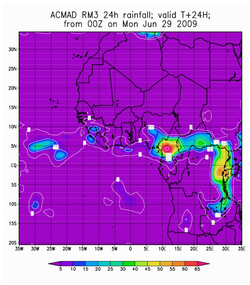
Our regional model, the RM3, is run simultaneously at the African Center of Meteorological Application for Development (ACMAD) and at NASA GISS. The model uses .5 º (~ 50km) spacing between points, which is a higher resolution than most global models, which usually use points 2º apart. The area of interest is marked by the coordinates 35W-35E, and 35N-20S. 28 different layers of altitude are also used, resulting in 111 x 141 x 28 data points. In order for the model to run, it needs to be provided with boundary data that corresponds to the area surrounding the region of interest. The lateral boundary conditions in the latest experiments are provided by the Global Forecast System (GFS).

24 vs. 48 Hour Forecasts

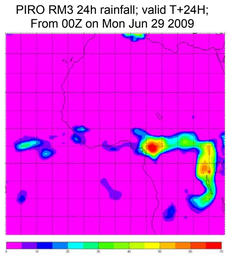


24 Hour RM3 Forecast | **48 Hour RM3 Forecast** | **TRMM**

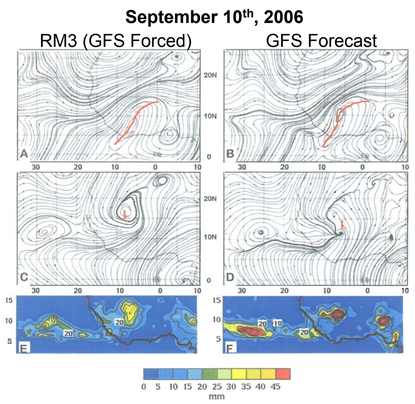
The RM3 makes three different forecasts: 24, 48 and 72 hour predictions using the GFS Forcing data. In the images above, it is apparent that the both the 24 and the 48 hour forecasts show excessive rain. In comparison to the TRMM data (top right), the RM3 appears to show a positive bias.



The RM3 is run simultaneously at ACMAD in Niamey, Niger and at NASA GISS in New York. The machine at GISS is called PIRO. To make sure that both models are working in the same way, we compared the output of both models for the same forecast on a given day.



September 10th, 2006



700 mb wind circulations

925 mb wind circulations

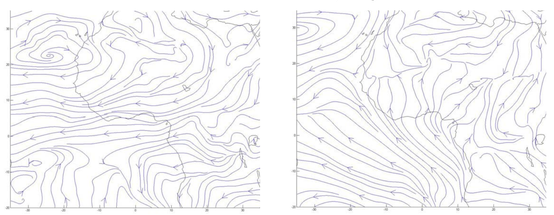
Sahel region precipitation

Climate patterns over the African Continent are highly dependent on the wind patterns in the Intertropical Convergence Zone. Moisture picked up by these low-altitude winds is then transported upwards by collisions of different air masses. Once at an altitude of approximately 3km (where the average pressure is about 700 mb), this moisture has the potential to become precipitation. The African Easterly Jet carries this moisture, usually centered around low-pressure systems, towards the west across the continent and the Atlantic Ocean. Occasionally these systems develop into tropical storms or hurricanes that arrive in the Americas.

A vital phenomenon that is studied at NASA GISS is African Easterly Wave Disturbances. These long undulations of wind in the African Easterly Jet give westward pressure systems additional cyclonic energy to develop into more severe storms. These undulations can be seen at 700mb and the corresponding cyclones at the wave troughs at 925mb. The corresponding precipitation around the cyclone confirms that this system was a storm worth monitoring. This storm, which crossed the African Atlantic Coast on September 11-12 2006, developed into a tropical depression on September 12th, Tropical Storm Helene on September 14th, and finally Hurricane Helene on September 16th. (Plots by Dr. Leonard Druyan et al.)

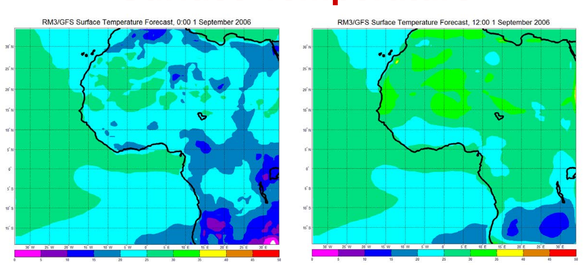
Predicting Winds

GFS-Forced RM3, July 2nd 2009



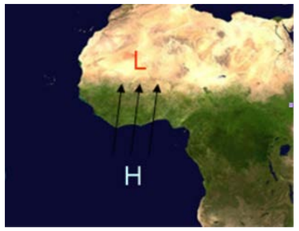
700 mb | 925 mb

Surface Temperature



One of the many climatic variables that are studied using the RM3 is surface temperature. The figures to the left show the diurnal temperature variation on the African Continent for September 1st, 2006. The sea surface temperature represents predictions by NCEP GFS and the temperature over land represents output from the RM3 forced by this data. Accurately modeling temperature is essential for determining pressure gradient across West Africa, which is essential for the simulation of wind circulation as well as cyclones and anticyclones.

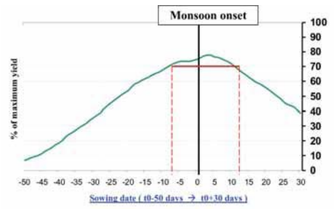
Monsoons



The monsoon season in West Africa occurs annually from June to September and is characterized by winds blowing from the ocean onto the Sahelian belt. The area where North and Southeast winds merge is called the Intertropical Convergence Zone (ITCZ). It shifts Northward during the monsoon season, causing precipitation in the Sahelian belt. The local economy, which consists of a large agricultural sector, depends greatly on these seasonal rains.

Onset

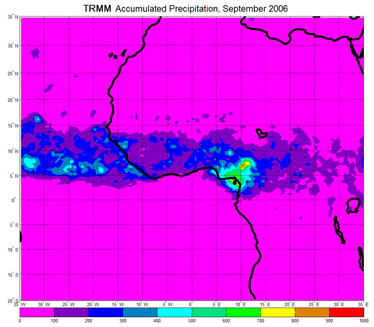
The primary definition of the onset of the monsoon season is an agricultural one. The onset is defined by one or two consecutive days with greater that 20 millimeters of rain, without a 7 day dry spell with less than 5 millimeters in the 20 days following. This definition is cautious not to falsely predict the onset of the season, because doing so can be detrimental to the crop yield. To maximize crop yield, crops should be sowed close to the large-scale onset date.



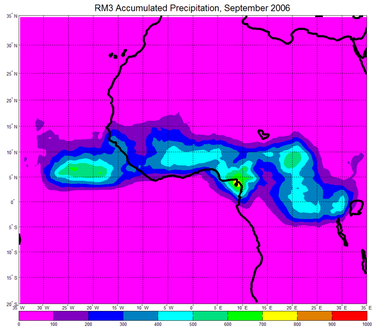
Easterly Waves

The West African monsoon season has other effects as well. Easterly Waves, waves that propagate westward towards the Caribbean, are one of the consequences of the North-South temperature gradient and the mid-tropospheric jet stream. These waves have been linked to most of the tropical storms that reach the Caribbean and Southern Florida.

TRMM

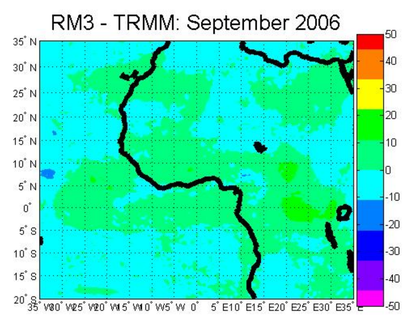


RM3



Average Daily Rainfall: September 2006

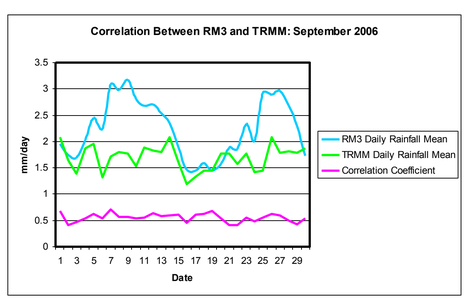
Correlation Coefficient: 0.7818



TRMM, or Tropical Rainfall Measuring Mission, is a global satellite measuring precipitation. TRMM data is recorded in near-real time, but is updated by calibrating it against gauges. According to the plots to the left, the RM3 seems to overestimate rain in comparison to TRMM.

Future Work

To continue the study into climate change over West Africa, validation and modification of the model will continue at NASA GISS. In order to test its capabilities, the model will be driven by different datasets and tested against each other. The continued study of West African climate will assist the ability to predict seasons of heavy rainfall as well as drought.



Sponsors:

National Aeronautics and Space Administration (NASA)
NASA Goddard Space Flight Center (GSFC)
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NASA New York City Research Initiative (NYCRI)

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